SUBSTITUTE SPECIFICATION

METHOD FOR CALIBRATING AN OPHTHALMIC LENS DRILLING MACHINE, DEVICE FOR THE IMPLEMENTATION OF THIS METHOD, AND EQUIPMENT FOR MACHINING OPHTHALMIC LENSES EQUIPPED WITH THIS DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a method for calibrating an ophthalmic lens drilling machine, the machine including a drilling tool; an ophthalmic lens support associated with a first coordinate system; and a programmable tool guidance means associated with a second coordinate system expressing command coordinates which define a target drilling point. In the method the following successive steps are carried out. A template is placed on the support, the template having pre-applied markings defining a third coordinate system related to the template, such that the third coordinate system is made to substantially coincide with the first coordinate system. The template is drilled in at least one predetermined point corresponding to a target point defined by predetermined command coordinates, such that a real drilling point is obtained.

Figure 1 shows schematically an ophthalmic lens drilling machine of a known type, which essentially comprises a support 2 on which a lens can be mounted and fixed for grinding, a drilling tool 3 which can be moved in a controlled way with respect to the support 2, and means 11 for guiding the tool 3.

The support 2 is shown schematically in the form of a receptacle enabling ophthalmic lenses of different shapes to be fixed with respect to the frame, in a fixed coordinate system O_1, X_1, Y_1 associated with the support 2. The support 2 is provided to hold the ophthalmic lens in a support plane which is assumed to be horizontal. The reference axes X_1, Y_1 are therefore assumed to be horizontal.

The support 2 which is shown is a receptacle having an internal shape complementary to that of an adapter, of the type conventionally used to fix the lens on the movable arm of a grinder. An adapter of this kind is fixed, by gluing for example, to one of the faces of the lens. The receptacle 2, which is intended to receive an adapter of this type by insertion, has an indexing shape 2A complementary to an indexing shape of the adapter, which enables the lens to be orientated on the support 2, and thus with respect to the frame of the machine 1. The indexing means 2A thus define the orientation of the support 2 and of the frame of the machine, in other words the coordinate system O_1, X_1, Y_1.

The drilling tool 3 is defined as being a tool which removes material around an axis, assumed in this case to be vertical (orthogonal to the axes X_1, Y_1), in the thickness direction of the lens, over a virtually point-like region of the lens or one having an area much smaller than the area of the lens. The term "drilling" can denote a conventional operation of drilling with a drill bit, resulting in the formation of a hole with a substantially circular cross section, or else an operation of "notching", resulting in the formation of a notch in the edge of the lens, or any other type of more complex milling.

The guidance unit 11 for guiding the tool 3 are provided to move the tool 3 according to a machining task to be carried out on a lens placed in the machine. For this purpose, these guidance unit 11 comprise driver 13 adapted to move the tool 3, and controller 15 for controlling the driver 13, adapted to deliver to the driver 13 a command signal C corresponding to the machining task to be performed. The controller 15 is programmable means; it is provided to store a certain number of control laws with parameters set according to the shape and position of the drilling to be carried out. Thus the sequence of movements and operations executed by the tool 3, defined by the command signal C, is a function of the shape and position parameters supplied to the input of the controller 15. These parameters are indicated in Figure 1 by the reference F (shape parameters) and by the references X, Y (position parameters). The position parameters X, Y are expressed in the second frame reference associated with the guidance unit 11, this virtual coordinate system theoretically coinciding with the first coordinate system O_1, X_1, Y_1 related to the support 2.

Figure 2 shows an ophthalmic lens 21 of generally rectangular shape, having a center marking O_3 and axis markings X_3, Y_3 on one of its faces.

The center O_3 represents the optical center of the lens 21, and the axis X_3 represents its optical axis. The purpose of the marking of the axis Y_3, perpendicular to the axis X_3 in the general plane of the lens 21, is essentially to define the optical center O_3 at its intersection with the axis X_3.

When an adapter is centered on an ophthalmic lens blank for grinding, the center of the adapter coincides with the optical center O_3 of the blank.

Thus, after the grinding operation which results in the production of the lens 21 in its finished form, when the lens 21 with its grinding adapter is placed on the support 2 for drilling in the machine 1, the center of the support O_1 theoretically coincides with the optical center O_3 located by the axis markings X_3, Y_3 on the leans 21.

If a hole is then to be drilled in the lens 21 with the drilling machine 1, the position parameters X, Y and the shape parameter F must be supplied to the controller 15, as mentioned above. For example, in order to create a virtually point-like circular drilled hole, the position parameters X, Y consist of the coordinates of the center M of the drilled hole. The coordinates X, Y, which are expressed in the second coordinate system associated with the guidance means 11, theoretically represent the coordinates of the center of drilling M in the coordinate system related to the lens, in other words the third coordinate system O_3, X_3, Y_3.

When the drilling is actually carried out, it will be found that the real center of drilling (or real drilling point) M_r is offset with respect to the theoretical center of drilling (or target drilling point) M, as defined by the coordinates X, Y in the third coordinate system O_3, X_3, Y_3.

This situation is shown in Figure 3, in which the profile of the lens 21 and its markings defining the coordinate system O_3, X_3, Y_3 are shown in solid lines, and the indexing shape 2A and the associated coordinate system O_1, X_1, Y_1, as positioned with respect to the lens 21 when the latter is placed in the drilling machine 1 on the support 2, are shown in broken lines. The real centre of drilling M_r is also shown on the lens 21 in solid lines, and the theoretical centre of drilling M is shown in broken lines.

For reasons explained below, this offset is expressed by the coordinates dX, dY in one of the three pre-defined coordinate systems, which is assumed to be any one of these coordinate systems.

As a general rule, the offset of the real drilling points with respect to the theoretical drilling points is explained by the fact that the three coordinate systems defined above do not coincide exactly. On the one hand, the second coordinate system, associated with the guidance unit 11 and taken as the reference, for example, of the neutral position of the tool 3, is not exactly locked to the first coordinate system O_1, X_1, Y_1 related to the support 2. This is due to the manufacturing tolerances and to the wear of the mechanical components used in the adjustment of the neutral position of the tool, to the tolerances and wear of the mechanical components of the driver 13, and to the intrinsic inaccuracies of the control elements used in the feedback control of the position of the tool 3, for example. On the other hand, the third coordinate system O_3, X_3, Y_3 related to the lens 21 does not coincide exactly with the first coordinate system O_1, X_1, Y_1 related to the support 2. This is due, in particular, to the inaccuracy, even if very small, of the positioning of the adapter on the lens, and the inaccuracy of the fixing of the adapter

to the support 2, resulting, for example, from the manufacturing tolerances of these parts and from the possible deformation of the adapter during the preliminary grinding operation.

It should be noted that the offsets generally found in drilling machines between the theoretical and the real drilling points tend to indicate that there is no significant angular offset between the different coordinate systems. Consequently, in the description of the present invention, it is assumed that these coordinate systems are offset only with respect to translation, and that their horizontal axes, on the one hand, and their vertical axes, on the other hand, are parallel. This has been illustrated in Figure 3, between the first coordinate system O_1, X_1, Y_1 and the third coordinate system O_3, X_3, Y_3.

For drilling machines used at present, it is therefore necessary, before the first use of the machine, to estimate the offset between the real drilling points and the theoretical drilling points, and to calibrate the machine so as to introduce a correction of the control laws into the controller 15. These calibration operations can be renewed periodically thereafter throughout the service life of the machine.

The correction which is introduced takes the form of a change of variables. For example, the position parameters taken into account for the calculation of the command C are X + dX, Y + dY, in place of the input parameters X, Y.

In the prior art, these calibration methods are implemented on the basis of a "manual" measurement of the offset produced by the uncalibrated machine. In the prior art, an operator uses the uncalibrated machine to drill a succession of virtually point-like circular holes in a template, such as an ophthalmic lens, and measures the positions of these drilled holes on the template by means of a calliper gauge. The operator then deduces the offset of each drilled hole with respect to the theoretical drilling points, and introduces a corresponding correction into the programmable machine guidance means. This correction can, for example, take into account a mean of the offsets found over all the measurement points.

This method has two principal drawbacks, namely the low accuracy of the measurement of the offset (of the order of a 10th of a millimetre), and the considerable time taken for the operation.

SUMMARY OF THE INVENTION

The object of the invention is to propose a calibration method of the type described above, making it possible to obtain a marked increase in accuracy, and requiring a shorter operating time and markedly simpler manipulation operations. This object is achieved by a calibration method according to the invention, in which the following steps are executed in succession. First an image of the previously drilled template is created. the image is analyzed by image analysis unit, so as to measure the offset between the position of the real drilling point and the position of the target point; and the guidance unit is programmed so as to introduce a correction of the command coordinates capable of compensating for the offset.

Other characteristics of this method include the following. The markings defining the third coordinate system comprise markings which define a center and markings which define two orthogonal axes. During the drilling step, the template is drilled at two predetermined points, each corresponding to a target point defined by predetermined command coordinates, so as to obtain two real drilling points. The correction is based on a mean value of the offset of the position of the two real drilling points with respect to the respective two target points.

The invention also proposes a device for implementing a calibration method as described above. This device includes an image capture device; and an image analysis unit connected to the image capture device, adapted to detect the position of the image of a real drilling point of a template, in a coordinate system defined by the image of markings appearing on the template, and to calculate an offset of position of the image with respect to a predetermined target point defined by pre-recorded coordinates. In addition, the device includes a programming unit connected on the one hand to the image analysis unit and on the other hand to the guidance unit for guiding an ophthalmic lens drilling machine. The programming unit is adapted to receive an offset information element from the image analysis unit, and to program the guidance unit of the machine in response, so as to introduce a correction of the command coordinates as a function of the offset information.

According to other characteristics of the device according to the invention, the device additionally comprises a screen and light source for illuminating an ophthalmic object, enabling a shadow of the template to be projected on to the screen. The screen is placed in the field of observation of the image capture device. The device comprises a

transparent support to receive the template, positioned between the means of illumination (light source) and the screen. A collimator is positioned between the means of illumination and the transparent support to make the light rays emitted by the means of illumination substantially parallel to each other and normal with respect to the support. The screen is a ground glass; and the image capture device is a video camera.

Finally, the invention proposes equipment for machining ophthalmic lenses, includes a drilling machine which has a drilling tool, an ophthalmic lens support associated with a first coordinate system, and a programmable unit for guiding the tool, associated with a second coordinate system in which command coordinates defining a target drilling point are expressed. In addition, the equipment includes a device as described above, associated with the said drilling machine.

BRIEF DESCRIPTION OF THE DRAWINGS

A specific embodiment of the invention will now be described more fully with reference to the attached drawings, in which:

- Figures 1-3 are schematic diagrams illustrating a conventional ophthalmic lens drilling operation;

- Figure 4 is a schematic view of a device according to the invention; and

- Figure 5 is a partial view of the image of a template, as it may be observed by the image capture device of the device according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

In the calibration method according to the invention, a template is drilled by the uncalibrated machine 1, shown in Figure 1, as explained previously. In the illustrated example, this template 21 consists of an ophthalmic lens 21, as described with reference to Figure 2, but could be another ophthalmic object such as a template of plastics or other material, provided with center and axis markings.

The adapter of the template 21 is removed, and the template is then cleaned to remove any trace of adhesive originating from the adapter from the surface of the template, and to leave the markings associated with the coordinate system O_3, X_3, Y_3 visible on the surface of the template.

The coordinates dX, dY of the offset between the real drilling points M_r and theoretical drilling points M are then estimated by drilling calibration device 51 shown in Figure 4.

This drilling calibration device 51 comprises a flat transparent support 53 on which can be placed the drilled template (ophthalmic lens) 21, which has previously been separated from its adapter.

It also comprises a light source 55, a collimator 57, and a ground glass 59, positioned in such a way that the light rays emitted by the source 55 pass through the collimator 57 to be made parallel and orthogonally illuminate the template 21 placed on the support 53. This arrangement enables the drilled template and its markings O_3, X_3, Y_3 to be projected on to the ground glass 59.

The device additionally comprises an image capture device in the form of a video camera 61, image analysis unit 63 connected to the camera 61, and if necessary a display screen 65 connected to the image analysis unit 63. The screen 65 could also be connected directly to the camera 61.

The ground glass 59, forming a screen for the projection of the shadow of the object placed on the support 53, is placed in the field of the camera 61, in such a way that the camera 61 observes this projected shadow and transmits its image to the image analysis unit 63.

The device also comprises programming unit 64 connected, on the one hand, to the image analysis unit 63, and, on the other hand, to the guidance unit 11 for guiding the drilling machine 1.

Figure 5 shows the image 21I of the template 21 which is thus observed by the camera 61, as it appears on the screen 65.

The shadow of the drilled hole IM_r, and the shadows of the center marking IO_3 and of the axis markings IX_3, IY_3 appear distinctly in this image 21I.

The image analysis unit 63 is adapted to detect the image IM_r of the drilled hole formed in the template 21, and the image of the markings IO_3, IX_3, IY_3, calculate the position of the drilling point IM_r in this image coordinate system IO_3, IX_3, IY_3, and calculate in this coordinate system the coordinates of the offset dX, dY between the point M_r and the point M, which are assumed to be equal to the difference between the coordinates of the point IM_r in the coordinate system IO_3, IX_3, IY_3, on the one hand, and those of the point M in the second coordinate system.

The value of the offset dX, dY estimated in this way is transmitted to the programming unit 64.

If necessary, the offset can be measured for two or more distinct drilling points, rather than for a single point as described above. In the case of two distinct drilling points, the image 21I of the template 21 will then have a second image IM; corresponding to the second drilled hole in Fig. 5. The correction of the control laws can then be based on a mean of the offsets estimated in this way.

Thus the drilling calibration device 51 makes it possible to produce a precise estimate of the offset of a real drilling point with respect to a target point, and, because of its programming unit 64, automatically program the guidance unit 15 of the ophthalmic lens drilling machine so as to introduce a correction of the command laws dependent on the estimated offset coordinates dX, dY. The accuracy achieved by such a device and such a calibration method is of the order of a hundredth of a millimetre.

It should be noted that the drilling machine 1 and the associated device which have been described can be incorporated into ophthalmic lens machining equipment which also comprises a grinder. Thus it is possible to use a single piece of equipment to grind an ophthalmic lens, starting with a lens blank, and to drill the lens thus produced, by using the grinding adapter fixed on the lens to immobilize the lens on the drilling support.

The device described above can be used for calibrating not only the drilling machine, but also the grinder.